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CERAMIC MATERIALS AND PRODUCTS : TECHNIQUES OF SCIENTIFIC AND TECHNOLOGICAL CONTROL

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CERAMIC MATERIALS AND PRODUCTS -
- TECHNIQUES OF SCIENTIFIC AND TECHNOLOGICAL CONTROL

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1. INVESTIGATIONS FOR THE IMPROVEMENT OF THE TECHNOLOGICAL AND INDUSTRIAL APPLICATIONS OF A COUNTRY'S NATURAL RESOURCES.

Primitive peoples developped ways and means for utilizing the natural resources of their countries, each succeeding generation improving on the processes, as best as they could, not only to save labour, but to better the products. Taking any particular region of the world at its earliest times one finds the so-called traditional industries as the only existing ones, being slowly but steadily refined. During that region's early history few new industries can be seen to appear.

Later, as improved means of communication and transportation began making this a smaller world, in every country most secrets ceased to be. Then if some untapped natural resource still existed, it gave rise to new, borrowed industries, with few exceptions. Depending on how well a people could "take-in" a borrowed industry, it became with time a semi-traditional industry in that particular region.

A ceramic product and its main raw material, viz. porcelain and kaolin, can be used to illustrate this point. For many centuries, the Chinese were the only people utilizing their natural resources of kaolin for making porcelain and it was not until a couple of centuries back that European countries gained knowledge on porcelain manufacture. And then, this foreign or borrowed industry took such hold in some countries, especially France and Germany, as to become a semi-traditional industry there.

The transfer of knowledge is never a one-way affair and the beer industry - a traditional one in Germany - found its way into China. However this is still a "foreign" industry there and it may take many a year before it changes into semi-traditionalism. There are human factors that oppose the settling in of the industry and cannot be neglected. A successful transfer, for example, was that of a traditional industry from countries such as Portugal and France to South Africa, who borrowed and set-up a wine industry, already falling into semi-traditionalism there. These industries have one thing in common and that is the fact that it takes not only time, but the people's outlook towards them to really make a successful transfer.

As opposed to these, one finds another group of industries, which one can call the "universal" ones, e.g. the heavy chemicals, cements, petroleum products, pharmaceuticals, etc., which were born more out of science and technology than tradition, and although they must exist in any industrialised country to form the industrial bone-structure that cannot be given by the other types of industry considered above, they can hardly ever become

part of a nation's soul, so to speak.

These points are briefly summarized in table 1, and should be taken into consideration when planning the industrial reorganization of a country.

The establishment of universal industries is an easy process nowa-days, it is only the keeping up to world progress that must be internally assured. The borrowing of non-universal industries to suit a country's natural resources and her peoples nature is a more difficult task, with problems other than scientific and technological to be considered for successful transfer and adaptation, and while considering it, a country must concentrate most of her industrial research upon traditional industries, where the assistance is greatest to make use of scientific advances.

Although in Portugal there exist industries of the four types mentioned in table 1, the National Institute for Industrial Research, on setting forth to investigate the industrial applications of the Nation's natural resources - either animal, vegetable or mineral - concentrated its initial efforts on the most important traditional (and semi-traditional)industries.

Obviously enough, though, facilities were provided first for all and every industry by the installation of well- equipped and staffed analytical laboratories covering the fields of organic and inorganic chemistry ; bio-, electro-, and physical-chemistry; the establishment of a general scientific library and documentation centre; the setting up of an industrial economics centre; a bureau of industrial planning and productivity techniques; a metallurgy and corrosion nucleus; and so on.

Initial research centred on industries such as fishing and canned fish; timber and resinous products; cork; glass; ceramics; with already projected studies on wines, textiles, fruit and its canned-products; leather , sugar, etc.

It is some of the initial work done in setting up a ceramics unit that will be described.

2. PLAN OF ACTION AND FACILITIES AVAILABLE IN THE FIELD OF CERAMICS

a) Enquiries and contacts with the industry

Since the Ceramic Industry includes distinctive sub-industries, viz. porcelain, stoneware and whiteware, ordinary pottery and faiance,heavy clay products and refractories, any research program has to include as many sub-programs.

Generally speaking, and referring back to table 1, countries that have only traditional and semi-traditional industries (status A or B)possess primitive ceramic industries, usually producing only pottery and faiance, with perhaps an incipient heavy clay products sub-industry. Some of the more advanced countries (C) will have borrowed the techniques for manufacturing stoneware, whiteware and perhaps porcelain, along with a competent heavy clay products industry, but it is almost always the case that a refractories industries is absent until some of the universal industries are set-up

Statistics were collected and it was observed that in highly developed countries the refractories and heavy clay products sub-industries vied for first place in importance within the ceramics field, followed quite some distance away by whiteware, stoneware and porcelain, with ordinary pottery and faiance last.

Nation-wise surveys were made by first sending simple questionnaires, so worded and structured as to give the manufacturers full opportunity

for supplying all the requested information. Along with the questionnaires , were sent circular-letters requesting samples of all raw materials in use , and the formulations used for any particular manufacture.

As the answers were being received, visits to the plants were made not so much for the establishment of direct personnal contacts, but mainly to size up and classify the plants at the same time their particular technological problems were evaluated and tabulated.

b) Documentation

At the Institute's General Library a file was opened, comprising all data already available on ceramics, while more works were being ordered and subscriptions taken to the most important ceramic journals.

The whole collection of the "Chemical Abstracts" was followed up, entries on ceramics studied, the references and abstracts extracted and filed.

Filing is conveniently arranged by subjects and according to the decimal system of classification. Full informations can be obtained on any subject, by looking up the pertinent cards, referring back to the copied abstracts of the works and ordering of the required material through the General Library.

For any other data, such as statistics, help is always sought at the Institute's Information Centre, which ought to have all the answers.

c) Laboratory facilities

Since most manufacturers of whiteware and porcelain possess fairly well equipped control laboratories at their plants, and since another Government entity - the National Laboratory of Civil Engineering - is equipped for testing heavy clay products, the initial facilities were directed towards control of raw materials and manufacturing processes, with emphasis on the fields of refractories and heavy clay products.

A selection was made of the methods and techniques for scientific and technological control of ceramic raw materials and manufacturing cycles and technical personnel was trained in the application of those techniques, which were standardized.

All facilities available at the Institute's other centres are always at the disposal of the Ceramics Unit for any work beyond the immediate capability of this unit, which could start off with the minimum of initial capital outlay and can grow in a precisely controlled manner, in exact accordance with the industry's needs and demands. Also, in the rare cases where special work be required, involving expensive or specialised equipment not yet available at the Institute, cooperation is assured from other Government Services, and even private concerns.

A small all purpose ceramic pilot-plant is planned to grow within the Unit, for industrial research on unit processes and a provisional list of the equipment that will make up the complete unit appears in table 2.

To facilitate as much as possible the handling of materials for analysis, special entry books are kept, every material receiving an identification number. A work schedule is set up by the laboratory supervisor, on the appropriate work distribution sheet, which is handed over to the analyst with the material and the reporting sheets that cover all tests, analyses and determination to be done.

In Table 3, there is shown part of a work distribution sheet (for clay-type raw materials) and in Table 4 is given an actual example of a report sheet (on workability index).

From each collection of report sheets on any given material is made out the final analysis report, copy of which is sent to the interested party.

c) Collection of samples and classification

In the few cases where samples were not returned with the questionnaires, they were collected during the visits to the plants. All samples were progressively analysed and tested, priority being granted to the heavy clay products raw materials, for the reasons already mentioned, viz. the relative importance of the different ceramic sub-industries and the existance of plant laboratories in most whiteware and porcelain factories.

In addition to full testing of each clay, particular attention was given to the study of the technological properties of the different clay mixtures used. As is known, it is seldom that one is lucky enough to find a natural clay deposit that yields a raw material exactly meeting one's needs.

In this way, to obtain products with the required properties, producers have to select and mix two or more clays. Without sufficient scientific backing and technological control it is almost impossible to reach the ideal compositions and empirical tests yield only approximate results. A simple case, in brief outline, will help illustrate the point. A brick and roofing tile plant had access to three different clays, that can be called A, B and C, respectively. By trial-and-error they had arrived at the following raw clay compositions; for bricks, 1/3 each of A, B and C; for tiles, 5 parts of A, to 3 parts of B, to 2 parts of C. The products were well within existing building standard specifications and no difficulties were experienced in marketing the ware. However, complaints were often heard from roofing tile buyers, especially about growth of fungi on the roofs. Physical and chemical analysis of the clays helped in classifying them, but it was the tests on fired molded specimens that fully revealed each clay's technological properties. Triaxial plots were made to obtain the property-lines, i.e., the direction of change with composition for any given characteristic, such as colour, resistance to abrasion, water absorption, density and so on. A simplified plot is given in Figure 1, with some of the property-lines indicated, that give a clear picture of the problem. It was found that the mixture in equal parts was, indeed, nearly ideal for brick-making, since the only shift in composition that would not lower the water absorption capacity (which is required for the laying of the bricks) nor the resistance and hardness (beside other factors not shown in the figure) had to move within the Y-area. However, any shift in the Y-area, even, would affect the colour of the finished product (not to mention other characteristics again) and so the composition used should not be changed. As regards the tiles, improvement was possible, for most properties could be bettered for compositions within the X-area, although the shift in composition had to be limited by other factors such as firing shrinkage and texture of finished ware. Tests on mixtures of the three clays confirmed the results and the information was made available to the manufacturer, who can now produce better tiles by using a mixture of 3 parts A to 1 part each of B and C, instead of the original composition.

This is only one among many cases where scientific and technological control helped better a product, but it shows how really simple the tests can be that will benefit an industry which has grown heedless to science and technology.

3. FINDINGS OF THE PRELIMINARY SURVEYS AND INVESTIGATIONS

a) Standard terminology

When planning the questionnaires it was feared that no standard terminology existed in the Country, and care had to be observed in setting

out the names of products that might be used by the industry. For example, one of the items was marked simply 'CLAYS", with blanc lines following for the types to be filled in by the users, no attempt being made to even exemplify with words such as "bauxitic","burley","diaspore", and so on. These fears were fully justified as the answers proved.

A similar disturbing lack of standard terminology was observed with respect to raw materials other than clays, as well as to materials in the various stages of manufacture, to manufacturing unit processes themselves and to even the plant equipment. Regarding finished products, however, the position was generally good all over the Country, and if manufacturers can reach agreement here, there is no reason why the same cannot be done on all ceramic terms.

b) Porcelain, Stoneware and whiteware:

This was found to be a rather flourishing group and with good reason, too, for if not scientific, at least technological control was being conscienciously applied.

These producers are aware of the necessity to keep up with all technical advances, by direct pressure from the buyers, who know just what they are looking for and who are not prepared to pay for inferior quality ware, when they know there is, or can be, better, national or imported. So, in order that good-quality reputation be established, and maintained, manufacturers have to keep the strictest control on raw-material input, along the processing and on product output.

In general, these plants possess small but fairly well equipped and staffed laboratories controlling raw materials as received and after preliminary treatments at the plant. It is unfortunate, but there still does not exist in the Country any reliable group of ceramic raw material suppliers who can guarantee and maintain quality of supplies, a vacuum that must be filled as soon as possible.

These laboratories usually control manufacturing cycles, which are set to rigid norms, and also perform routine tests on finished products. In limited scale, some applied research is also carried out, but in a rather unscientific and selfish way, with little or no cooperation amongst the different producers. Upon completion of the Institute's Ceramic Unit, all research can be concentrated with obvious benefits.

c) Ordinary Pottery and Faiance:-

The few large faiance plants that exist are facing a difficult period, sales declining in spite of increased exports, and, without sufficient technical resources to change this tide, a slow death is very definitely setting in. There still exist all over the Country a host of small works producing ordinary pottery and their future is still more doubtful.

These fields have remained impervious to all scientific advances Most plants are under-staffed and these manufacturers do not have in their vocabularies the word "mechanization". Controls are purely empirical and even kiln temperatures are seldom measured and recorded. Raw materials are never analysed, being simply tried out and when they prove well, the largest possible amount is bought and stocked to avoid for as long a time as possible new tests when re-stocking. Quality of the finished ware is also seldom controlled except for looks and obvious body failures and defects. Unless something be done by properly oriented basic research at the Ceramics Unit this group will soon have to cease production altogether as their products are unable to meet modern users demands and compete with aluminium, cement and plastic ware.

d) Bricks and Ceramic Tiles:-

Ceramic tiles and building bricks are usually made to standard shapes and sizes and some technological progress has entered the field, generally, although there is still little control on raw-materials and on the mechanical and physical properties of the products, with a few notable exceptions.

Like the porcelain, stoneware and whiteware field, this is a flourishing one, but a striking difference can be observed in the way growth is taking place in one and the other field. There is order and continuous quality improvement in the former, in direct contrast with the brick and tile industry. The main reason for the difference is not that bricks are easier to make than porcelain and so everybody wants to "have a crack" at making bricks and not porcelain. The main reason is that in the first-mentioned field the buyers are usually the end-users, who will just not take an inferior quality product, while in the heavy clay products the buyers are seldom the end users, being usually builders, who naturally enough care more about shape and price than quality. It is mainly because of this that internal competition is so great in this field, quality being sacrified for price. This is a case where rigid standard specifications and norms must be enforced at the same time an official standards and testing laboratory is set up taking charge of the spreading and teaching of modern control techniques for raw materials and manufacturing processes. That this route can and does lead to the desired goals is proved by the success attained by the self-imposed controls that are at work in the porcelain and whiteware industries.

Mention should be made here of the refractories industry, still in its infancy in the Country and which can be considered as a universal one (referring back to table 1), not needing much help, except in the study of locally available raw materials, since manufacturing and testing know-how can be obtained when plant and test equipment is bought.

4. CONCLUSIONS AND RECOMMENDATIONS

a) Standards and Testing Laboratories:-

As could be inferred from the related facts, a standards and testing Laboratory is a real necessity as far as the ceramics Industries are concerned, but it is not sufficient that standards and norms be set and enforced for finished products with the pertinent official testing facilities. It is necessary that in the same way and at the same time standards and norms be established for raw materials, and scientific and technological counsel made available to all manufacturers. A laboratory of this type must be equipped and staffed so as to be able to study all ceramic raw materials, intermediate and finished products, as well as unit processes. In addition, short and long-term research programs must be persued for the benefit of the industry, and facilities provided for technical training of manpower for the industry, with abstracting of selected ceramic literature to be made generally available.

b) Plant controls:-

Ceramic plants should have the following functions properly applied -control of quality, inspection and guarantee of quality, Quality control is the responsability of the supervisors, who must have the minimum of technical training. The plant laboratory must be in charge of inspection and collecting of samples and other information of technical nature through the supervisors as well as routine analysis and tests. The guarantee of quality must rest with the technical director and/or an official standards and testing laboratory. Other types of control, such as statistics, must obviously be applied as in any other industry, and need not be mentioned.

c) International Terminology, norms and standards:-

Although much is already being done to set up international glossaries and technical standards, data have not been made generally available and it would greatly help the ceramics industry if the results so far obtained were revealed. Tentative proposals should be put to the test immediately in order that final and proved glossaries, norms and standards for ceramics raw materials and products be internationally agreed on as soon as possible, and before new nations on the way to industrialization set up ceramic industries, develop their own standards and norms, and so complicate the issue.

APPENDIX

TABLE 1 - BROAD CLASSIFICATION OF INDUSTRIES

TYPE OF INDUSTRY	1. TRADITIONAL	2. SEMI-TRADITIONAL	3. FOREIGN (BORROWED)	4. UNIVERSAL
EXAMPLES IN PORTUGAL	Fishing (canning) Fruit (canning) Wines Cork products	Ceramics Timber, Resins Textiles Leather	Glass Sugar Oils Beer	Petroleum prods. Heavy chemicals Cements Metal smelting
GENERAL TENDENCES	To develop slowly but steadily	To become traditional	To develop and become established too rapidly, then fall into types 2,1	To become every country's need rarely falling into types 2,1
NEEDS AND CARES	Very often new blood is needed Seldom can help be sought abroad Basic research must be carried out Producers must be educated.	Same as for 1. Usually help can be obtained abroad and so cooperation is needed as well as basic research.	Country-wise initial selling-out of the idea is needed as well as technical and financial help. Growth must be controlled.	Considerable investments are necessary but plants and know-how can be purchased. Must keep up to world progress
COUNTRY'S INDUSTRIAL STATUS A	▨			
B	▩	▩		
C	▨	▨	▨	
D	▩	▩		▩
E	▨	▨	▨	
INTER-RELATION	← · →			

TABLE 2 - EQUIPMENT FOR THE COMPLETE CERAMICS UNIT

One petrographic, one binocular, one projection (for microphotography) and one heating (for sintering and melting points) microscope; X-ray diffraction apparatus; dilatometer; rotational-type viscosimeter; differential thermal analysis apparatus; plasticity, particle-size and base-exchange equipment; thermogravimetry balance; complete laboratory equipment for chemical analyses; pH Meter and recorder; standard sieves and shaker; laboratory types ovens and mufles; flame spectography equipment; turbidimeter; colorimeter and brightness meter; water-deioniser; small centrifuge; flask-shaker; mechanical stirrers; Bouyoucos hydrometers; pyrometric cone equivalent furnace; hydraulic presses and moulds; apparatus for deformation-under-load; panel spalling furnace (ASTM type); transverse strength apparatus; equipment for thermal conductivity (ASTM type); sound analyser, for ring test; abrasion test equipment; jaw crushers; disc type grinding machine; ball-mill; vibratory screens with magnetic separators; floatation cells; dry and wet pans; de-airing extruder; electric ovens and kilns; air elutriator; large centrifuge; jiggering machines; settling tanks; filter presses; pipe formers; glazing and painting equipment; pelletizer, for bloating clays; Mace sinter hearth apparatus (for light weight aggregates) and drilling machine, for clay deposits.

TABLE 3 - WORK DISTRIBUTION SHEET

0.1	CLAYEY MATERIALS	DETERMINATIONS AND TESTS FOR SAMPLE NO										DATE- ANALYST-	
Report no.	TESTS	REQUIRED DETERMINATIONS											Date finished
1.1	Chemical analysis	Ign. loss	SiO_2	Al_2O_3	R_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2			
1.2	Particle-size (sieving)	Use sieves			Draw Graphs			Method					
		No.	to No.		A	B	C	Dry	Wet				
1.3	Particle-size (hydrometer)	TAKE READINGS FOR ___ DAYS ___ HOURS											
1.4	Particle-size (Pipette)	TAKE READINGS FOR ___ DAYS ___ HOURS											
1.5	pH-Deflocculation	pH as received ☐			Addition Na_2CO_3 ☐			Graph ☐					
etc.	etc.	etc.											

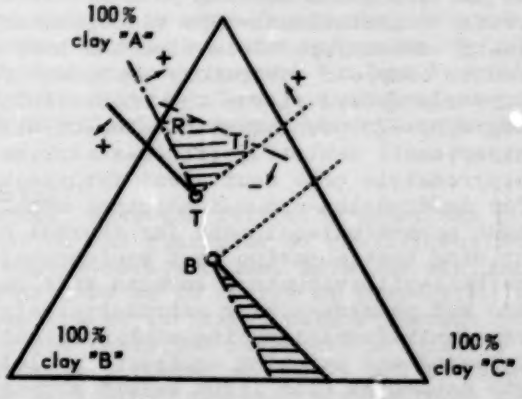
TABLE 4 - EXAMPLE OF TEST REPORTING SHEET

1.9	Workability Index	REPORT ___ SAMPLE NO.	Date- Analyst-

ASTM RAMMER. FOUR TESTS ON 300g. EACH. TEN IMPACTS, UPEND, TEN IMPACTS. TAKE LENGTH WITH SUSPENDED WEIGHT (A CM.) LOWER WEIGHT. THREE IMPACTS LENGTH (B)

SPECIMEN NO.	READINGS		DIFFERENCE (D=A-B)	WORKABILITY INDICES (100D÷ A)
	A (CMS)	B (CMS)		
1.				
2.				
3.				
4.				
If specimen crumbles report here			AVERAGE	

B = Brick composition
T = Original tile composition
Ti = Improved tile composition
R = Region of coarser texture



---------- Colour lines
—·—·—·— Resistance lines
———— Absorption lines
— — — — Shrinkage lines

Fig. I - Property-lines plot

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